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Study on the correlation between dynamic monitoring of peripheral blood cell-related inflammatory indicators and clinical prognosis of traumatic brain injury

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Abstract: To explore the correlation between dynamic monitoring of peripheral blood cell-related inflammatory indicators and clinical prognosis of traumatic brain injury, 201 patients with traumatic cerebral hemorrhage were enrolled and divided into good (n=74, mRS 0–2) and poor (n=127, mRS 3–6) prognosis groups based on discharge mRS score. Inflammatory indicators were compared, and multivariate logistic regression was used to identify risk factors. Significant differences were found in age, admission GCS, combined trauma, preoperative PLR and SIRI, postoperative 1d NLR, and 3d NLR and MLR (all $P<0.05$). Multivariate analysis showed that age (OR=5.018), admission GCS (OR=2.474), preoperative SIRI (OR=2.587), postoperative 3d NLR (OR=2.566), and 3d MLR (OR=3.653) were independent risk factors (all $P<0.05$). ROC analysis revealed AUCs for preoperative SIRI, 3d NLR, and 3d MLR as 0.612, 0.783, and 0.722, respectively, while the combined logistic model achieved an AUC of 0.868, with higher sensitivity and specificity than any single variable. Preoperative SIRI, postoperative 3d NLR, and 3d MLR are associated with clinical prognosis of traumatic cerebral hemorrhage, and their combination improves predictive performance.

1. Introduction

Traumatic Brain Injury (TBI) is one of the most common and critical emergencies in neurosurgical intensive care units. The disease has a sudden onset, rapid progression, and complex pathophysiological mechanisms, leading to a persistently high mortality rate [1]. Traditional views often regard inflammatory responses as secondary events following traumatic brain injury and neglect dynamic monitoring of relevant inflammatory markers [2]. In fact, inflammation and secondary vascular injury are core components of secondary brain injury after TBI [3]. Following primary injury, extensive neuronal necrosis triggers inflammatory cell infiltration, including

neutrophils, lymphocytes, and monocytes, within the brain tissue, while peripheral blood cell counts also undergo significant changes [4]. In recent years, a series of novel composite inflammatory markers derived from peripheral blood cells—such as the neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), monocyte-to-lymphocyte ratio (MLR), systemic immune-inflammatory index (SII), and systemic inflammation response index (SIRI)—have garnered widespread academic attention. Existing studies have confirmed that NLR, PLR, and SII have good prognostic value for patients with TBI; however, research on the predictive efficacy of MLR and SIRI remains insufficient [5,6]. Moreover, previous studies have neglected the assessment of dynamic changes in these markers. Therefore, this study aims to deeply investigate the correlation between dynamic changes in NLR, PLR, MLR, SII, and SIRI at different time points after admission and poor prognosis in TBI patients, evaluate the clinical application value of these markers in prognostic assessment of TBI patients, and provide new evidence-based support for developing more precise individualized treatment strategies and improving patients' quality of survival.

2. Materials and methods

2.1 Research subjects

A retrospective analysis was conducted on the clinical data of 201 patients with traumatic brain injury admitted to the Department of Neurosurgery of our hospital from January 2020 to May 2025, including 134 males and 67 females. According to the patients' mRS (modified Rankin Scale) scores at discharge, they were divided into a good prognosis group (n=74, mRS score 0-2) and a poor prognosis group (n=127, mRS score 3-6).

2.2 Inclusion and exclusion criteria

Inclusion criteria: ① Diagnosed with intracerebral hemorrhage by computed tomography (CT); ② The intracerebral hemorrhage was caused by trauma; ③ All patients underwent surgical treatment.

Exclusion criteria: ① Patients who received conservative treatment; ② Patients who had pre-existing infectious diseases before hospitalization; ③ Patients with severe coagulation dysfunction, severe abnormalities of heart, liver, kidney or other organ functions, as well as immune system disorders; ④ Patients with incomplete medical records; ⑤ Patients who died within 3 days of hospitalization.

2.3 Method

The general clinical data of patients after admission were collected, including age, sex, history of hypertension, history of diabetes mellitus, presence of other concomitant injuries, presence of intraventricular hemorrhage, Glasgow Coma Scale (GCS) score on admission, and operative duration. Peripheral blood cell parameters, including neutrophil, lymphocyte, monocyte, and platelet counts, were measured before surgery, on postoperative day 1, and on postoperative day 3. The following composite inflammatory markers were then calculated: neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), monocyte-to-lymphocyte ratio (MLR), systemic immune-inflammatory index (SII), and systemic inflammation response index (SIRI). This study is a retrospective study. Patient data were anonymized during use, and informed consent was waived in accordance with the requirements of the Ethics Committee.

2.4 Statistical analysis

Statistical analysis was performed using SPSS 23.0 statistical software. The normality of continuous data was tested. Continuous data with a normal distribution were expressed as mean ± standard deviation (±s), and comparisons between two groups were conducted using the t-test. Continuous data with a non-normal distribution were expressed as median (interquartile range) [M, (Q1, Q3)], and comparisons between two groups were performed using the Mann-Whitney U test. Categorical data were expressed as number (percentage) [n (%)], and comparisons between two groups were performed using the chi-square test. Receiver operating characteristic (ROC) curve analysis was used to determine the cut-off values of variables that were statistically significant in the univariate analysis, and the area under the ROC curve (AUC), sensitivity, and specificity were calculated. Multivariate logistic regression analysis was used to identify risk factors for prognosis of traumatic brain injury. A P value < 0.05 was considered statistically significant.

3. Results

Among all the 201 patients with craniocerebral trauma who met the inclusion criteria, the median age was 58 years old, 134 males and 67 females. There were 104 patients with GCS score less than 11 at admission, 99 patients with other trauma, 12 patients with ventricular hemorrhage, 39 patients with hypertension, and 16 patients with diabetes. The median operation time was 180 minutes.

3.1 Univariate analysis of poor prognosis in enrolled patients

Table 1 Comparison of general data between the two groups of patients

Factors	Good prognosis group (n=74)	Poor prognosis group (n=127)	P-value
Gender[n(%)]			0.179
Male	29(39.2%)	38(29.9%)	
Female	45(60.8%)	89(70.1%)	
Age (years)	53(37.5,59)	61(55,69)	＜0.001
GCS score at admission (<11)[n(%)]	22(29.7%)	82(64.6%)	＜0.001
History of hypertension[n(%)]	10(13.5%)	29(22.8%)	0.107
History of diabetes[n(%)]	4(5.4%)	12(9.4%)	0.307
Combine with other injuries[n(%)]	25(33.8%)	63(49.6%)	0.029
Combined intraventricular hemorrhage[n(%)]	3(4.1%)	6(4.7%)	0.825
Surgery Duration (Minutes)	162(120,210)	180(150,240)	0.142

The median age of patients with poor prognosis at discharge was 61 years old, which was significantly higher than that of patients with favorable prognosis (53 years), with P < 0.001.The proportion of poor prognosis at discharge in patients with GCS < 11 was 64.6%, which was significantly higher than that in patients with favorable prognosis (29.7%), with P < 0.001.The proportions of combined other trauma in patients with poor prognosis and favorable prognosis were 49.6% and 33.8%, respectively, and the difference was statistically significant (P = 0.029).There were no significant differences between the two groups in gender (P = 0.179), proportion of

complicated intraventricular hemorrhage (P = 0.852), proportion of hypertension (P = 0.107), proportion of diabetes mellitus (P = 0.307), or operation duration (P = 0.142) (Table 1).

Table 2 Comparison of peripheral blood parameters between the two groups

Peripheral blood indices	Good prognosis group (n=74)	Poor prognosis group (n=127)	P-value
Preoperative NLR	11.244(5.629,18.361)	11.637(6.971,17.75)	0.488
Preoperative PLR	169.042(104.6145,259.49)	132.143(83.221,219.658)	0.039
Preoperative MLR	0.615(0.375,0.963)	0.721(0.459,1.174)	0.085
Preoperative SII($\times10^9$/L)	1774.944(952.119,3197.124)	1757.26(928.155,2776.222)	0.992
Preoperative SIRI($\times10^9$/L)	7.336(3.812,10.824)	9.322 (5.246,15.883)	0.007
Postoperative 1d NLR	12.486(9.541,19.604)	15.164(11.486,21.429)	0.030
Postoperative1d PLR	189.898(136.931,269.701)	173.554(110.938,249.333)	0.680
Postoperative 1d MLR	0.909(0.572,1.235)	0.983(0.681,1.462)	0.080
Postoperative 1d SII($\times10^9$/L)	2054.033(1302.557,2856.119)	1723.250(1011.969,2601.417)	0.183
Postoperative 1d SIRI($\times10^9$/L)	7.641(4.506,13.888)	10.231(6.296,15.622)	0.033
Postoperative 3d NLR	6.654(4.402,9.587)	11.8(7.773,16.686)	＜0.001
Postoperative 3d PLR	146.079(114.051,195.106)	158(109.804,225.926)	0.408
Postoperative 3d MLR	0.601(0.499,0.918)	0.926 (0.714,1.218)	＜0.001
Postoperative 3d SII($\times10^9$/L)	1058.860(697.839,1473.227)	1357.862(892.698,1853.333)	0.006
Postoperative 3d SIRI($\times10^9$/L)	4.814(2,662,8.578)	7.690(5.402,12.451)	＜0.001

NLR:neutrophil-to-lymphocyte ratio, PLR:platelet-to-lymphocyte ratio, MLR:monocyte-to-lymphocyte ratio, SII:systemic immune-inflammatory index, SIRI:systemic inflammation response index

The median preoperative PLR level in patients with poor prognosis at discharge was 132.143, which was significantly lower than that in patients with good prognosis (169.042), P = 0.039. The median preoperative SIRI levels in patients with poor and good prognosis were 9.322 and 7.336, respectively, and the difference between the two groups was statistically significant (P = 0.007). The postoperative day 1 NLR level (15.164 vs. 12.486) and SIRI level (10.231×10⁹/L vs. 7.641×10⁹/L) were significantly higher in patients with poor prognosis than in those with good prognosis (P < 0.05). The postoperative day 3 NLR level in patients with poor prognosis was 11.800, significantly higher than that in patients with good prognosis (6.654, P < 0.001). The postoperative day 3 MLR level in patients with poor prognosis was 0.926, significantly higher than that in patients with good prognosis (0.601, P < 0.001). The postoperative day 3 SII level (1357.862×10⁹/L vs.

1058.860×10⁹/L, P = 0.006) and SIRI level (7.690×10⁹/L vs. 4.814×10⁹/L, P < 0.001) were also significantly higher in patients with poor prognosis than in those with good prognosis. There were no significant differences between the two groups in preoperative NLR level (P = 0.488), MLR level (P = 0.085), SII level (P = 0.922); postoperative day 1 PLR level (P = 0.68), MLR level (P = 0.08), SII level (P = 0.183); or postoperative day 3 PLR level (P = 0.408) (Table 2).

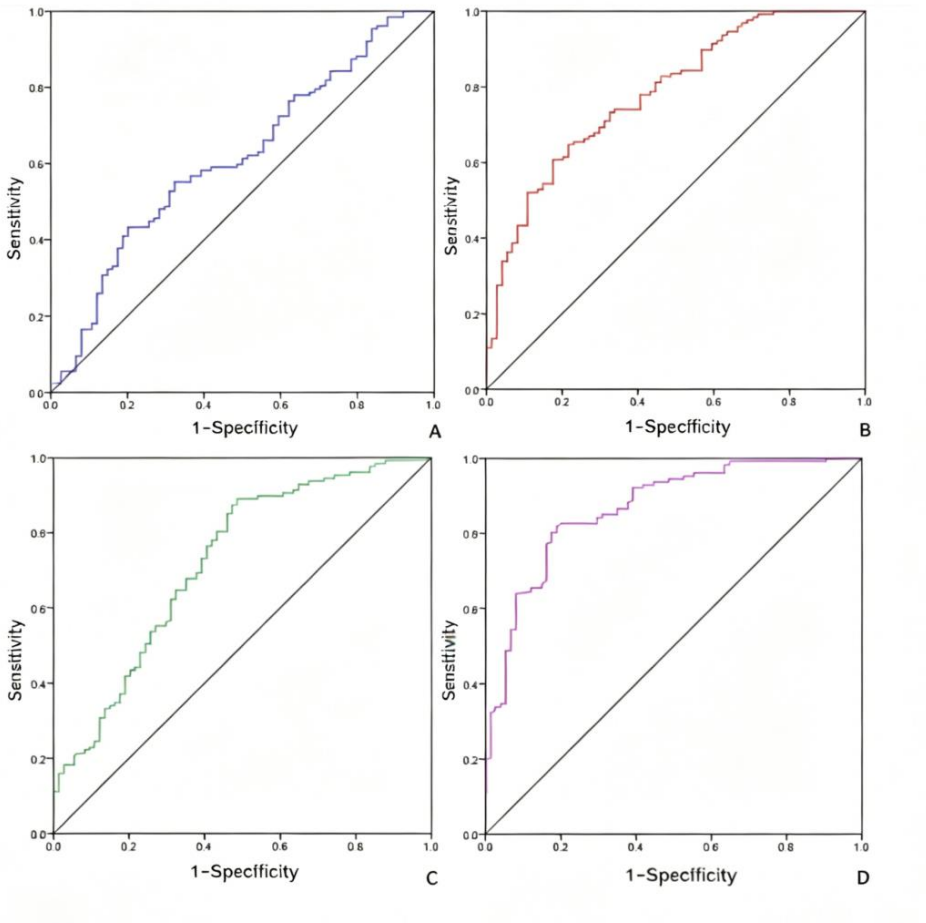
3.2 Multivariate analysis of poor prognosis in enrolled patients

Multivariate logistic regression analysis was performed including age, admission GCS score, combined other trauma, preoperative PLR and SIRI, NLR and SIRI on postoperative day 1, as well as NLR, MLR, SII and SIRI on postoperative day 3.The results showed that age (OR = 5.018, 95% CI: 2.181–11.545, P < 0.001), admission GCS score (OR = 2.474, 95% CI: 1.124–5.447, P = 0.024), preoperative SIRI (OR = 2.587, 95% CI: 1.015–6.593, P = 0.047), NLR on postoperative day 3 (OR = 2.566, 95% CI: 1.021–6.449, P = 0.045), and MLR on postoperative day 3 (OR = 3.653, 95% CI: 1.265–10.552, P = 0.017) were independent risk factors affecting the prognosis of traumatic brain injury (Table 3).

Table 3 Multivariate Logistic regression analysis of prognosis in patients with traumatic intracerebral hemorrhage

Variable	B	SE	P-value	OR value	95%CI	
					Lower limit	Upper limit
Age (years)	1.613	0.425	＜0.001	5.018	2.181	11.545
GCS	0.906	0.403	0.024	2.474	1.124	5.447
Combine with other injuries	0.578	0.403	0.151	1.783	0.809	3.927
Preoperative PLR	-0.668	0.424	0.115	0.513	0.224	1.176
Preoperative SIRI	0.95	0.477	0.047	2.587	1.015	6.593
Postoperative 1dNLR	-0.169	0.445	0.704	0.844	0.353	2.02
Postoperative 1dSIRI	0.868	0.45	0.054	2.381	0.986	5.753
Postoperative 3dNLR	0.942	0.47	0.045	2.566	1.021	6.449
Postoperative 3dMLR	1.296	0.541	0.017	3.653	1.265	10.552
Postoperative 3dSII	-0.037	0.498	0.941	0.964	0.363	2.558
Postoperative 3dSIRI	0.091	0.585	0.876	1.096	0.348	3.45

Among these, the cut-off value of preoperative SIRI for predicting poor prognosis was 10.929×10⁹/L, with an AUC of 0.615 (95% CI: 0.534–0.695). The cut-off value of postoperative day 3 NLR for predicting poor prognosis was 9.838, with an AUC of 0.783 (95% CI: 0.718–0.847). The cut-off value of postoperative day 3 MLR for predicting poor prognosis was 0.606, with an AUC of 0.722 (95% CI: 0.647–0.796). The AUC value of the multivariate Logistic regression analysis model was 0.868 (95% CI: 0.816–0.919), with a sensitivity of 81.9% and a specificity of 81.1% (Figure 1).



A: PreoperativeSIRI (AUC)=0.615; B: Postoperative3dNLR (AUC)=0.783;
C: Postoperative3dMLR (AUC)=0.722; D: Joint model (AUC)=0.868.

Figure 1 Sensitivity and specificity analysis of preoperative SIRI, postoperative 3-day NLR, postoperative 3-day MLR, and combined model in predicting prognosis

4. Discussion

Patients with traumatic brain injury often develop midline shift and cerebral herniation due to elevated intracranial pressure. Surgical treatment is an important clinical means of controlling intracranial pressure [7]. However, the postoperative prognosis of patients is influenced by multiple factors, such as age, pre-existing underlying diseases, coagulation dysfunction, electrolyte disturbances, and intraoperative cerebral edema [8]. Recent studies have indicated that the inflammatory response plays a key role in secondary brain injury following traumatic brain injury. The inflammatory response exacerbates brain injury through multiple mechanisms, including disruption of the blood–brain barrier, oxidative stress, microglial activation, platelet activation, microthrombus formation, and systemic inflammation [9–11]. These mechanisms intertwine to form a vicious cycle, ultimately leading to neuronal damage and multiple organ dysfunction, significantly affecting patient prognosis [12].

In terms of prognostic prediction, traditional indicators such as age and Glasgow Coma Scale (GCS) score on admission have been widely recognized [13]. In recent years, novel inflammatory markers such as the neutrophil-to-lymphocyte ratio (NLR), monocyte-to-lymphocyte ratio (MLR), and systemic inflammation response index (SIRI) have shown good predictive value for the

prognosis of stroke patients [14,15]. MLR is the ratio of monocytes to lymphocytes. Lymphocytes are involved in immune regulation and modulation of the inflammatory response; a decrease in their number may indicate an immunosuppressive state [16]. Monocytes play an important role in inflammatory injury of the body; therefore, MLR can reflect the dynamic balance between inflammation and immune status [17]. Existing studies have demonstrated that MLR has some value in predicting the prognosis of acute ischemic stroke [18]. Furthermore, Wang et al. [19] showed that a higher NLR is positively correlated with the risk of death at three months after stroke. The present study further confirms that NLR on postoperative day 3 (OR = 2.566) and MLR on postoperative day 3 (OR = 3.653) are independent risk factors for the prognosis of traumatic brain injury.

The systemic inflammation response index (SIRI), which is based on peripheral blood neutrophil, monocyte, and lymphocyte counts, was first reported in pancreatic cancer in 2016 and has been used for prognostic assessment of patients with various malignant tumors [20]. Currently, there are few reports in the domestic and international literature on SIRI in relation to traumatic brain injury. Mao et al. [21] found that during the 30-day and 365-day follow-up periods in patients with traumatic brain injury, patients with low SIRI levels had significantly improved survival compared to those with high SIRI levels. Cox regression analysis revealed that a higher SIRI value was an independent risk factor for death in trauma patients. In all patients in the present study, preoperative SIRI (OR = 2.587) was also an independent risk factor affecting clinical prognosis.

This study found that monitoring hematological inflammatory indicators before and after surgery is of great significance for predicting the clinical prognosis of patients with traumatic brain injury. Moreover, the detection methods for these hematological inflammatory indicators are simple and low-cost, making them suitable for clinical application. However, this study has certain limitations, such as a small sample size, inconsistent cutoff values for inflammatory indicators, and the potential impact of brain atrophy in elderly patients on the accuracy of GCS scores [22-23]. Future research should involve larger-sample, multicenter prospective studies to further validate the clinical value of these inflammatory indicators and explore more optimized prediction models.

5. Conclusion

In conclusion, the inflammatory response plays an important role in secondary brain injury following traumatic brain injury. Preoperative SIRI, as well as postoperative NLR and MLR at 3 days, may be associated with patients' clinical prognosis. In clinical practice, appropriate predictive indicators should be selected according to patients' individual conditions, and comprehensive judgment should be made in combination with clinical manifestations and other examination results, so as to more accurately evaluate patient prognosis and optimize treatment strategies.

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